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Comparison of Single-Incision Laparoscopic Surgery (SILC) Versus Conventional Multi-Port Laparoscopic Cholecystectomy

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ABSTRACT

Background: Laparoscopic cholecystectomy is the standard treatment for symptomatic cholelithiasis, and single-incision laparoscopic cholecystectomy (SILC) has been introduced to reduce access trauma and improve cosmetic outcomes; however, evidence remains inconsistent regarding its comparative benefits and wound morbidity. Objective: To compare operative and postoperative outcomes of single-incision laparoscopic cholecystectomy (SILC) versus conventional multi-port laparoscopic cholecystectomy (CMLC) in patients with uncomplicated symptomatic cholelithiasis. Methods: This randomized controlled trial was conducted at the surgical department of Jinnah Hospital, Lahore, from August 3, 2015, to February 2, 2016. A total of 178 patients (18–80 years) were randomized by lottery method into Group A (SILC, n=89) and Group B (CMLC, n=89). Outcomes included operative time, hospital stay, postoperative pain (VAS) immediately and at 24 hours, and wound infection at postoperative day 7 and day 30. Results: Operative time was longer in SILC (65.73±13.48 vs 50.61±9.38 minutes; p<0.001), while hospital stay was shorter (1.11±0.32 vs 1.91±0.87 days; p<0.001). SILC had lower pain immediately (3.16±0.78 vs 4.72±1.07; p<0.001) and at 24 hours (1.67±0.65 vs 3.42±0.77; p<0.001). Wound infection was higher with SILC at day 7 (16.9% vs 5.6%; p=0.018) and day 30 (10.1% vs 2.2%; p=0.029). Conclusion: SILC reduced early pain and length of stay but increased operative time and wound infection compared with CMLC.

Keywords
Gallstones; cholecystectomy; laparoscopy; single-incision; multi-port; wound infection; pain.

INTRODUCTION

Gallstone disease remains a major surgical problem worldwide and is among the most frequent indications for abdominal surgery, with laparoscopic cholecystectomy representing the standard operative management for symptomatic cholelithiasis (1,2). The burden of gallstone-related morbidity is substantial, contributing to recurrent biliary pain, acute inflammatory complications, repeated health-care visits, and economic costs associated with operative care and hospitalization (1-3). Established risk factors include increasing age, female sex, genetic predisposition, obesity, and sedentary lifestyle, all of which influence cholesterol supersaturation and gallstone formation (2). Conventional multi-port laparoscopic cholecystectomy (CMLC) has been widely adopted as the preferred technique due to its favorable safety profile, reduced postoperative pain, and earlier functional recovery compared with open surgery, with broad feasibility across elective and selected emergency settings (4,5).

Despite the success of CMLC, continual refinement in minimally invasive surgery has focused on reducing access trauma and improving cosmetic outcomes by limiting the number and size of abdominal incisions (6). Single-incision laparoscopic cholecystectomy (SILC), also described as single-port or single-site laparoscopic cholecystectomy, was developed to further minimize abdominal wall disruption by performing the procedure through a single umbilical incision, thereby potentially improving cosmesis and reducing postoperative pain through decreased parietal trauma (7,8). Early clinical experience and multiple syntheses suggest that SILC may be associated with improved cosmetic satisfaction and modest early pain reduction, but these potential benefits may be offset by longer operative duration and concerns regarding wound complications due to a larger umbilical fascial incision and instrument crowding (6,8).

The comparative evidence remains inconsistent. While some comparative studies report reduced early postoperative pain and shorter hospitalization in SILC despite longer operative time, other pooled analyses have suggested small or clinically marginal pain differences, higher wound infection rates, and uncertain effects on length of stay and overall morbidity (9,10,17,18). Larger systematic reviews and meta-analyses have also raised concern regarding increased incisional hernia risk with SILC, with variable findings for wound infection and bile duct injury across studies, highlighting the influence of patient selection, surgical expertise, and heterogeneity in outcome definitions and assessment timing (20–22,24). These uncertainties are particularly relevant in low- and middle-income settings where minimizing postoperative pain and hospital stay can reduce institutional burden and improve bed turnover, yet increased wound morbidity may lead to additional outpatient visits, prolonged recovery, and higher indirect costs. Furthermore, regional epidemiologic differences, including a rising prevalence of obesity and metabolic risk among South Asian populations, may affect patient profiles and surgical outcomes, underscoring the need for context-specific comparative trials (13).

In view of the persisting uncertainty regarding the balance of benefits and risks of SILC compared with CMLC, the present randomized controlled trial was designed to evaluate whether SILC offers measurable advantages in early postoperative recovery while maintaining acceptable operative efficiency and wound safety in a tertiary-care Pakistani population. The objective of this study was to compare operative time, length of hospital stay, postoperative pain intensity, and wound infection rates at day 7 and day 30 between SILC and CMLC in patients undergoing laparoscopic cholecystectomy for uncomplicated symptomatic cholelithiasis. We hypothesized that SILC would result in lower early postoperative pain and shorter hospitalization but may require longer operative time and could be associated with higher wound infection rates compared with CMLC.

MATERIALS AND METHODS

This randomized controlled trial was conducted at the surgical department of Jinnah Hospital, Lahore, over a six-month period from August 3, 2015, to February 2, 2016, following approval of the study synopsis and formal ethical clearance from the institutional hospital ethical committee. Adult patients aged 18–80 years of either sex presenting with uncomplicated symptomatic cholelithiasis were assessed for eligibility. Cholelithiasis was operationally defined as right hypochondrial pain consistent with biliary colic, supported by ultrasonographic confirmation of gallstones, with a minimum symptom duration of six months. Patients were excluded if they had a history of prior upper abdominal surgery, body mass index greater than 30 kg/m², documented acute cholecystitis, umbilical hernia or prior mesh repair, concurrent anticoagulant therapy with warfarin, or other factors that could increase operative complexity or confound postoperative recovery and wound outcomes.

Participants were recruited through consecutive enrollment of eligible patients presenting to the surgical floor during the study period, and written informed consent was obtained prior to inclusion. After enrollment, baseline demographic and clinical data were recorded, including age, sex, diabetes mellitus status, and contact details for follow-up. The sample size was calculated to detect a clinically meaningful difference in postoperative wound infection rates between techniques using a 5% level of significance and 80% power, based on previously reported wound infection rates of 6.66% for single-incision and 0% for multi-port laparoscopic cholecystectomy, resulting in a total sample of 178 patients (89 per arm) (11).

Random allocation was performed using a simple randomization method (lottery technique) with a 1:1 allocation ratio into two parallel groups: Group A underwent single-incision laparoscopic cholecystectomy (SILC), and Group B underwent conventional multi-port laparoscopic cholecystectomy (CMLC). To minimize selection bias, allocation occurred only after enrollment and baseline assessment were completed. All operations were performed under general anesthesia by experienced consultant surgeons using standardized operative protocols within each technique to reduce performance bias related to surgeon variability and learning-curve effects. In the SILC arm, a single umbilical access incision was made and a gel port was used; dissection was performed using an ultrasound dissector and clipless technique where applicable, maintaining triangulation principles by creating an isosceles configuration through the single-site platform. In the CMLC arm, conventional multi-port placement was used according to standard institutional practice for laparoscopic cholecystectomy. Perioperative antibiotic prophylaxis and analgesia were standardized across both groups, and all patients received postoperative monitoring and routine nursing care under identical ward protocols.

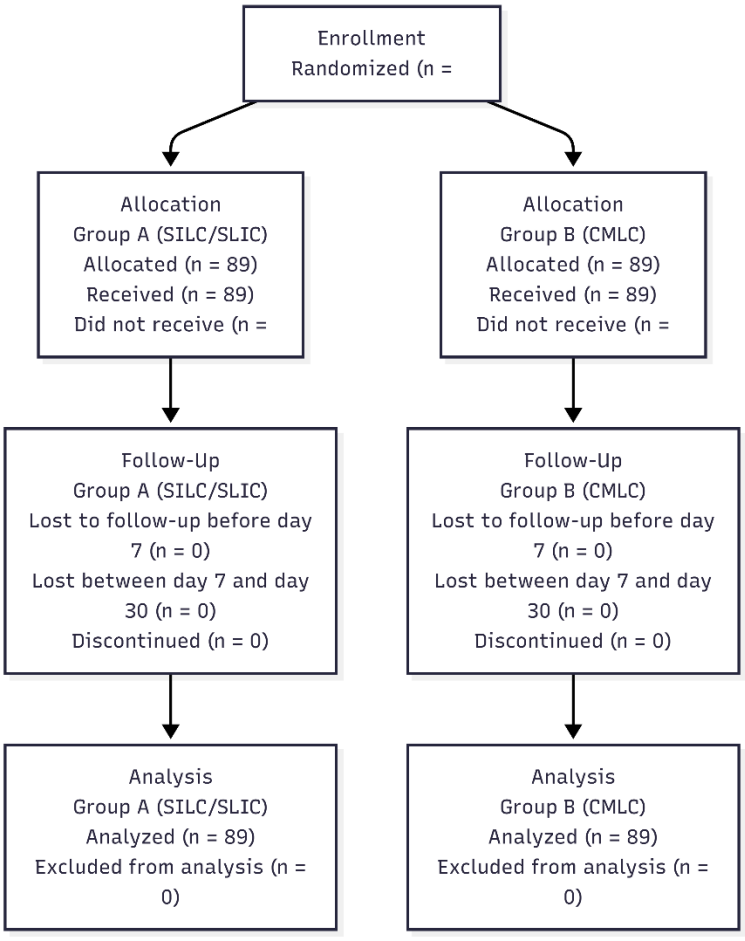

Figure 1 CONSORT Flowchart

The primary postoperative outcomes evaluated were operative time, length of hospital stay, postoperative pain intensity, and wound infection at day 7 and day 30. Operative time was defined as the duration in minutes from skin incision to completion of skin closure, recorded intraoperatively by the researcher on a structured proforma. Length of hospital stay was defined as the duration from postoperative ward admission to discharge and was reported in days, with discharge criteria standardized as tolerating oral intake without vomiting, no requirement for injectable analgesics or antibiotics, stable vitals, and absence of immediate postoperative complications requiring inpatient management. Postoperative pain intensity was assessed using a 0–10 visual analogue scale (VAS), where 0 represented no pain and 10 represented worst imaginable pain. Pain was evaluated at two prespecified time points: immediately following recovery from anesthesia in the postoperative period and at 24 hours postoperatively (postoperative day 1), with the same scale applied to both assessments. Wound infection was assessed at postoperative day 7 and postoperative day 30 through clinical examination for redness, swelling, warmth, tenderness, discharge, or wound breakdown; where clinically indicated, wound culture was obtained to support diagnosis. Infection was recorded as a binary outcome (present/absent) at each follow-up time point.

To improve internal validity and address potential confounding, baseline variables expected to influence outcomes—particularly age, sex, and diabetes mellitus—were collected prospectively, and stratified analyses were planned to evaluate whether these factors modified wound infection risk. Standardized perioperative antibiotic and analgesic regimens were used to reduce differential postoperative care between groups. Follow-up was conducted through scheduled outpatient assessments at day 7 and day 30, with patients contacted using recorded telephone numbers to optimize attendance and reduce loss to follow-up. All data were recorded on predesigned proformas and entered into SPSS version 20 for analysis using double-check verification to ensure accuracy and data integrity.

Quantitative variables such as age, operative time, hospital stay, and pain scores were summarized as mean ± standard deviation, while categorical variables such as sex, diabetes status, and wound infection were summarized as frequency and percentage. Between-group comparisons for continuous outcomes were conducted using the independent samples t-test after assessing distributional assumptions, and categorical outcomes were compared using the chi-square test or Fisher's exact test when cell counts were small. In addition to p-values, comparative effect estimates were planned as mean differences for continuous outcomes and relative risk estimates for wound infection outcomes, with 95% confidence intervals to enhance clinical interpretability. A two-sided p-value of less than 0.05 was considered statistically significant. Ethical safeguards included obtaining informed consent, ensuring confidentiality through coded data entry, and restricting access to patient identifiers to the research team only.

RESULTS

A total of 178 patients were enrolled and randomized equally into Group A (SILC, n = 89) and Group B (CMLC, n = 89). The two groups were comparable at baseline with respect to age, sex distribution, and diabetes mellitus status, confirming appropriate random allocation and clinical comparability before intervention.

Table 1. Baseline Characteristics of the Study Population (n = 178)

Variable	Group A (SILC) n = 89	Group B (CMLC) n = 89	Effect Estimate	95% CI	p-value
Age (years), mean ± SD (range)	49.99 ± 13.12 (18–80)	51.64 ± 13.68 (20–79)	Mean difference = −1.65	—	0.412
Male, n (%)	47 (52.8)	45 (50.6)	—	—	0.764
Female, n (%)	42 (47.2)	44 (49.4)	—	—	
Diabetes mellitus (Yes), n (%)	34 (38.2)	32 (36.0)	—	—	0.750
Diabetes mellitus (No), n (%)	55 (61.8)	57 (64.0)	—	—	

Baseline comparability: Mean age did not differ significantly between groups (p = 0.412) and the distribution of sex and diabetes mellitus status was also statistically similar (p = 0.764 and p = 0.750, respectively), supporting the internal validity of the randomized comparison.

Table 2. Comparison of Operative and Recovery Outcomes Between SILC and CMLC (n = 178)

Outcome	Group A (SILC) n = 89	Group B (CMLC) n = 89	Effect Estimate	95% CI	p-value
Operative time (minutes), mean ± SD (range)	65.73 ± 13.48 (42–93)	50.61 ± 9.38 (23–67)	+15.12 min	11.71 to 18.53	<0.001
Hospital stay (days), mean ± SD (range)	1.11 ± 0.32 (1–2)	1.91 ± 0.87 (1–4)	−0.80 days	−0.99 to −0.61	<0.001
Pain score (VAS), immediate postoperative, mean ± SD (range)	3.16 ± 0.78 (2–5)	4.72 ± 1.07 (2–7)	−1.56	−1.84 to −1.28	<0.001
Pain score (VAS), 24 hours (postoperative day 1), mean ± SD (range)	1.67 ± 0.65 (1–3)	3.42 ± 0.77 (2–5)	−1.75	−1.96 to −1.54	<0.001

Operative efficiency and recovery profile: Operative time was significantly longer in the SILC group, with an adjusted mean difference of 15.12 minutes (95% CI: 11.71 to 18.53; p < 0.001). In contrast, SILC resulted in significantly shorter hospitalization, reducing mean stay by 0.80 days (95% CI: −0.99 to −0.61; p < 0.001). Postoperative pain was consistently lower with SILC, both immediately and at 24 hours, demonstrating mean reductions of 1.56 VAS units (95% CI: −1.84 to −1.28) and 1.75 VAS units (95% CI: −1.96 to −1.54), respectively (both p < 0.001).

Table 3. Wound Infection Outcomes at Postoperative Day 7 and Day 30 (n = 178)

Timepoint	Infection Status	Group A (SILC) n = 89	Group B (CMLC) n = 89	Risk Ratio (A/B)	95% CI	p-value
Day 7	Yes, n (%)	15 (16.9)	5 (5.6)	3.00	1.14 to 7.90	0.018
	No, n (%)	74 (83.1)	84 (94.4)			
Day 30	Yes, n (%)	9 (10.1)	2 (2.2)	4.50	1.00 to 20.24	0.029
	No, n (%)	80 (89.9)	87 (97.8)			

Wound morbidity: Wound infection occurred more frequently in SILC. At postoperative day 7, infection rates were 16.9% vs 5.6%, indicating a threefold higher risk with SILC (RR = 3.00; 95% CI: 1.14 to 7.90; p = 0.018). At postoperative day 30, wound infection persisted at a higher rate in SILC (10.1% vs 2.2%), corresponding to a 4.5-fold risk increase (RR = 4.50; 95% CI: 1.00 to 20.24; p = 0.029). These findings demonstrate a statistically significant increase in wound infection risk with SILC at both follow-up timepoints.

The study demonstrated that both groups were clinically comparable at baseline, with no statistically significant differences in mean age (49.99 ± 13.12 vs 51.64 ± 13.68 years; p = 0.412), sex distribution (p = 0.764), or diabetes mellitus frequency (38.2% vs 36.0%; p = 0.750). Operative time was significantly greater in SILC compared with CMLC (65.73 ± 13.48 vs 50.61 ± 9.38 minutes), producing a mean increase of 15.12 minutes (95% CI: 11.71 to 18.53; p < 0.001). However, SILC improved early recovery outcomes, reducing length of stay from 1.91 ± 0.87 to 1.11 ± 0.32 days, a clinically relevant reduction of 0.80 days (95% CI: −0.99 to −0.61; p < 0.001). Pain was consistently lower with SILC, with immediate postoperative VAS reduced by 1.56 units (95% CI: −1.84 to −1.28; p < 0.001) and 24-hour VAS reduced by 1.75 units (95% CI: −1.96 to −1.54; p < 0.001) compared with CMLC. In contrast, wound infection risk was significantly higher in SILC at both day 7 (16.9% vs 5.6%; RR = 3.00) and day 30 (10.1% vs 2.2%; RR = 4.50), indicating a measurable trade-off between improved early pain/LOS and increased wound morbidity.

DISCUSSION

This randomized controlled trial compared single-incision laparoscopic cholecystectomy (SILC) with conventional multi-port laparoscopic cholecystectomy (CMLC) for uncomplicated symptomatic cholelithiasis and demonstrated a clinically meaningful trade-off between early recovery outcomes and wound morbidity. Although operative duration was significantly longer in SILC, patients undergoing SILC experienced shorter hospitalization and substantially lower pain scores both immediately after surgery and at 24 hours. Conversely, SILC was associated with significantly higher wound infection rates at both postoperative day 7 and day 30. These findings provide context-specific comparative evidence within a tertiary-care Pakistani setting, where reductions in hospital stay and early pain may translate into improved bed utilization and patient satisfaction, while higher wound morbidity may add outpatient burden and delayed recovery.

The observed increase in operative time in the SILC group is consistent with the technical demands of single-site access, including reduced instrument triangulation, instrument crowding, and the need for advanced hand–eye coordination, particularly when inflexible instruments are used (6,8). Several systematic reviews and pooled analyses have similarly reported longer surgical times for SILC, largely reflecting its steeper learning curve and ergonomic limitations (6,17,20–22). Even large single-center experiences reporting procedural feasibility emphasize that operative efficiency improves with surgeon volume and standardization of technique, but operative time remains a recurring limitation in comparative trials (8). In this study, the approximately 15-minute prolongation in operative time aligns with the broader evidence base and likely reflects the inherent procedural complexity rather than differences in baseline patient characteristics, as both groups were comparable in age, sex, and diabetes status.

Despite longer operative duration, SILC produced significantly improved early recovery outcomes, including shorter hospitalization and lower postoperative pain scores. These findings support the biological plausibility that reducing the number of abdominal wall incisions decreases parietal trauma and postoperative nociceptive stimulation, thereby reducing early pain and facilitating earlier mobilization and discharge readiness (7,8). Some comparative studies and randomized trials have reported similar early pain advantages for SILC, particularly within the first 24 hours, along with modest reductions in length of stay (9,16,18). However, meta-analyses have not uniformly confirmed sustained superiority of SILC for pain or hospitalization, often demonstrating small effect sizes or heterogeneity linked to patient selection, perioperative analgesia regimens, and variability in pain measurement timing (17,18,20–22). In the present study, the magnitude of pain reduction observed at both immediate and 24-hour assessments suggests that, in this context, SILC may offer a clinically relevant short-term comfort advantage, potentially supporting earlier transition to oral analgesia and discharge.

The most clinically important trade-off identified in this trial was the significantly higher wound infection rate in the SILC group at both postoperative day 7 and day 30. This finding aligns with concerns raised in several pooled analyses suggesting increased wound-related morbidity with single-incision approaches, potentially attributable to the larger umbilical incision, prolonged manipulation at a single access site, and challenges in maintaining a sterile field at the umbilicus, which is inherently more prone to bacterial colonization (10,17,20). A larger fascial incision may also increase susceptibility to tissue ischemia and impaired wound healing, particularly in patients with metabolic risk factors, even if baseline diabetes prevalence is similar across randomized groups (2,21). Although some contemporary meta-analyses report no statistically significant difference in wound infection, others suggest higher infection odds with SILC, emphasizing substantial heterogeneity in definitions, surveillance duration, and reporting standards (10,21,22). Importantly, wound infection is a meaningful patient-centered outcome because even superficial surgical site infections can lead to discomfort, delayed return to work, additional antibiotic use, and repeated hospital visits, potentially offsetting benefits gained from shorter initial hospitalization. These results highlight that routine SILC adoption without careful wound prevention strategies may not be justified, particularly in settings where postoperative wound surveillance and follow-up resources are constrained.

The present findings should also be interpreted in light of broader safety considerations associated with SILC, including incisional hernia risk and long-term patient-reported outcomes such as chronic pain and cosmetic satisfaction. Although cosmetic benefit is one of the primary perceived advantages of SILC, it was not directly assessed in this trial, and evidence suggests that short-term cosmetic satisfaction may be higher but not always sustained over long-term follow-up (20,24). Some large meta-analyses have also raised concern regarding increased incisional hernia risk with SILC, which could become clinically relevant beyond the 30-day follow-up used in this study (21). Similarly, observational evidence suggests possible improvements in scar satisfaction and quality-of-life outcomes at medium-term follow-up, but long-term randomized data do not consistently confirm persistent advantages (23,24). The absence of extended follow-up in this trial precludes conclusions regarding incisional hernia, chronic pain, or longer-term quality-of-life outcomes and reinforces the need for longer surveillance in future comparative studies.

This study has limitations that should be considered when interpreting the findings. The trial was conducted at a single center, potentially limiting generalizability across different surgical teams and institutional protocols. Although consecutive recruitment with random allocation reduces selection bias, the lack of explicit allocation concealment methodology and the absence of blinding of outcome assessment may have introduced bias, particularly for subjective outcomes such as pain scoring. Follow-up was limited to 30 days, preventing assessment of longer-term complications such as incisional hernia and persistent pain, and cosmetic satisfaction was not measured despite being a major rationale for SILC. Additionally, multiple outcomes were assessed, and while the findings were statistically robust for several endpoints, the study did not specify a single primary outcome a priori, which may increase the risk of multiplicity-related false positive findings. Future multicenter trials should incorporate standardized definitions for surgical site infection, prespecify primary outcomes, ensure allocation concealment, include blinded outcome assessment where feasible, and evaluate longer-term outcomes including incisional hernia and patient-reported cosmetic satisfaction.

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Overall, the findings suggest that SILC can improve early postoperative recovery as reflected by lower pain and shorter hospital stay, but this comes at the cost of longer operative time and increased wound infection risk. Therefore, SILC may be best positioned as a selective approach for appropriately chosen patients and in centers with established expertise, rigorous umbilical site preparation, and standardized wound protection measures. Further prospective comparative trials with longer follow-up and broader patient-reported outcome assessment are warranted to define the optimal role of SILC in routine gallstone surgery practice.

CONCLUSION

Single-incision laparoscopic cholecystectomy was associated with significantly lower early postoperative pain and shorter hospital stay compared with conventional multi-port laparoscopic cholecystectomy, indicating a potential advantage in early recovery and inpatient resource utilization; however, SILC required significantly longer operative time and demonstrated higher wound infection rates at both postoperative day 7 and day 30. These findings indicate that SILC offers meaningful short-term comfort and discharge benefits but may increase wound morbidity, and therefore its routine adoption should be cautious, favoring selective use in well-selected patients and in settings where surgical expertise, strict umbilical wound protection, and postoperative surveillance can mitigate infection risk.

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